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A

LABORATORY MANUAL

OF

ELECTROTHERAPEUTICS

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HIGH POTENTIAL, HIGH FREQUENCY CURRENTS.

Currents of high tension and of great frequency of alternations have long been known to the electro-therapeutist who is familiar with the action of the static machine. The discharge which takes place between the prime conductors of such a machine, when they are supplied with Leyden jars or condensers, is at times of this nature. During the small fraction of a second required for such discharge, which may be spoken of as an instantaneous current, the electric polarity changes many thousand times, in oscillations of gradually diminishing amplitude. When the arrangements during a treatment with the static machine in action is such as to make the patient on the insulated stool the terminus of the charge from one of the condensers, and a ball electrode connected to the other condenser is brought sufficiently near the person of the patient to permit a spark to pass, *i. e.*, the direct or indirect treatment by sparks, then, provided the relation of capacity to resistance is just right, the patient is subjected to a current of high frequency and high potential for the instant corresponding to each discharge. Again, the static machine may give rise to high frequency, high potential currents in what has been termed the *static induced circuit*, a current that is obtained in a circuit connecting the outer surfaces or armatures of the Leyden jars or condensers. The patient may be made a part of this circuit and so be subjected to the influence of these high potential, high frequency currents.

But as one of the important features of this peculiar electric modality in its relation to physiological and therapeutic action is the oscillatory character of the discharge, the static machine as it is customarily employed cannot be depended upon with certainty to furnish a discharge of this nature. Whether or not the spark discharge of the static machine is *impulsive* or oscillatory in character depends upon the relation which the capacity of the machine and condensers bears to the inductance and resistance of the circuit, and as certain of these terms vary from time to time, due to atmospheric conditions and manner of application the physical nature of the discharge likewise varies, and therefore the static machine, in the arrangement of its parts as now employed in therapeutics, does not furnish the high potential currents with such invariable regularity in number and frequency of the oscillations as is required for accuracy in scientific observations and comparison of results.

If the output of electric energy from the static machine was stabile and uniform the capacity of the condensers could be so adjusted to the resistance and inductance in the circuit as to secure constancy in the oscillatory nature of the discharge from them, but the obstacles to this end have not yet been overcome.

Other sources than the static machine have therefore been sought for and developed for generating high potential, high frequency currents. Tesla, Elihu Thomson and d'Arsonval have each been active in this search, and each in his independent line of investigation has made use of large induction coils as step-up transformers of the original electric energy, which in some instances is derived from alternating dynamos of low frequency and in others from some direct current source, as a dynamo, a primary or secondary battery. The low frequency of the alternating dynamo must be changed to a high frequency, and the constant or direct current must be broken up into sudden impulses with interruptions in order to furnish the

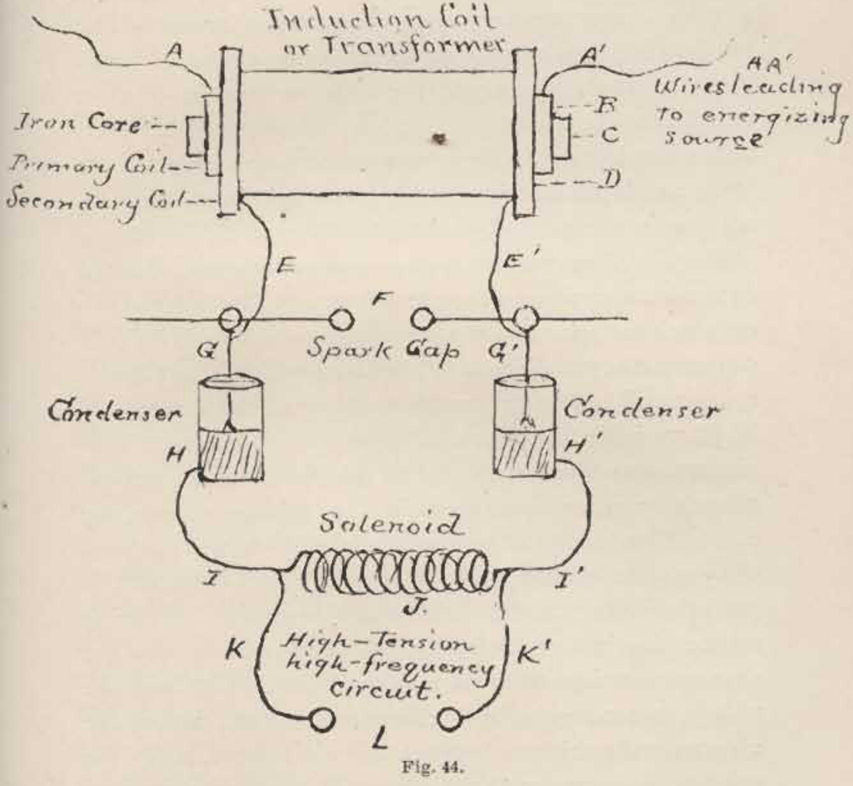
Induction Coil or Transformer
A
A'
AA' Wires leading to energizing source
Iron Core
Primary Coil
Secondary Coil
B
C
D
E
E'
F
Spark Gap
G
G'
Condenser
Condenser
H
H'
Solenoid
I
I'
J.
K
K'
High-Tension high-frequency circuit.
L

Fig. 44.

proper variations for inducing currents in the windings of the induction coil. These necessities give rise to some peculiarities in mechanism which have been variously constructed by the different inventors. The underlying principles by which the ultimate result is secured are the same in all. The accompanying diagram (Fig. 44) will illustrate the various steps in the process.

B C D is an induction coil or transformer whose primary coil is energized from some source, preferably an alternating current dynamo. If the energizing current is a direct current source then the primary circuit would need to be supplied with an interrupting device to break the current into periods, such as the spring vibrator attached to the ordinary induction coils or, what is better, a rotating disk driven by a motor and so arranged as to make and break the circuit with great rapidity and suddenness, as in the method devised by d'Arsonval. With the primary coil excited in either manner named, induced currents are created in the secondary coil D, the terminals of which are joined to the internal armatures of two condensers or Leyden jars G G′, between which is arranged a spark gap F. The external armatures of the condensers H H′ are joined through a solenoid J of copper wire large size and about 20 turns. When this system is in action, at each break or alternation in the primary circuit, the E. M. F. induced in the secondary coil charges the condensers. In proportion to the charge the difference of potential between the armatures increases. When it reaches the limit of the area of the ball terminals and the space separating them at the spark-gap, which may be many thousand volts, a discharge takes place across the air gap and oscillates between the condensers, while the solenoid J is traversed by a current of a frequency corresponding to the frequency of the oscillations. These oscillations are prevented from discharging into the circuit of the secondary coil because of its great self induction. When operating the system by energizing it from an alternating dynamo circuit the charging and discharging of the condensers is so frequently repeated that an arc is likely to form across the spark gap and so put an end to the oscillatory nature of the discharge. In order to prevent the formation of this arc Tesla and Thomson employed first, a strong magnetic field and later, an air blast at the spark gap.

When we compare the action of this system when energized by the alternating dynamo current, or the interrupted direct current, we find that with the first the inductive effects of the two waves of positive and negative potential are the same, so that when the alternation has a frequency of 124 periods per second as is customary with the ordinary alternating dynamo used for industrial purposes, there will be double the number or 248 single inducing waves each second. With the direct current interrupted a current effective in charging the condenser is induced in the secondary only at the instant of "make," so that to have the same number of useful waves as with the alternating dynamo current, it would be necessary for the interrupter to produce 248 contacts per second.

The currents that traverse the solenoid induced by the discharge of the condensers to the outer armature of which the solenoid is connected are those that are ordinarily utilized for therapeutic purposes. By connecting conductors to each end of the solenoid a circuit can be provided through which these currents can be conveyed. This may be termed the patient's circuit, for it is to the current generated at this point that the patient is, in one or the other manner, subjected.

By an additional device, that is another step-up transformer, these currents may be brought to generate others of still higher tension. These have been termed "currents of second order," and are obtained by having the solenoid of sufficient diameter to permit of placing within it a glass tube enclosing a coil of fine, well insulated wire, of many turns but a single layer. Currents of such extremely high potential are excited in this inner coil when the solenoid is excited that the glass tube surrounding the coil of fine wire needs to be filled with oil to serve as an insulator. The terminals of this fine wire coil brought out at the extremities of the glass tube through proper stoppers can then be connected up in any manner desired so as to exhibit the nature of these "currents of second order."

Hertz, Tesla and Thomson have each devised a number of beautiful and striking experiments by which to demonstrate the energy possessed by these high frequency and high potential currents. It was early discovered that they failed to excite the animal organism either in the form of sensation or muscular movement, and yet after traversing the body they render lamps and vacuum tubes incandescent, and in many ways exhibit an expenditure of electric energy which if applied to the animal body in one of many other forms would prove instantly destructive.

ESSENTIAL PROPERTIES OF HIGH POTENTIAL HIGH FREQUENCY CURRENTS.

As pointed out by Bordier, these currents are distinguished from ordinary alternating currents by three essential properties, which are due to both the great frequency and the high tension.

1st. They cause remarkable inductive effects.

The E. M. F. of induction near an inducing source is equal to the product of the intensity of the current by the frequency. Let us suppose a frequency of 500,000 periods per second and a mean current of 1 ampere. The E. M. F. in one turn would be the same as if a current of 100 amperes with a frequency of 50 should circulate in 10 turns of wire. Thus it is seen that with high frequency the E. M. F. induced in a single turn would be considerable. In a large solenoid the current induced in one turn is sufficient to illuminate by mutual induction a lamp of 8 volts and 1 ampere.

2nd. Currents of high frequency, even though the capacity be small, circulatė as well in open as in closed circuits, so that contact with only one pole suffices to give a current

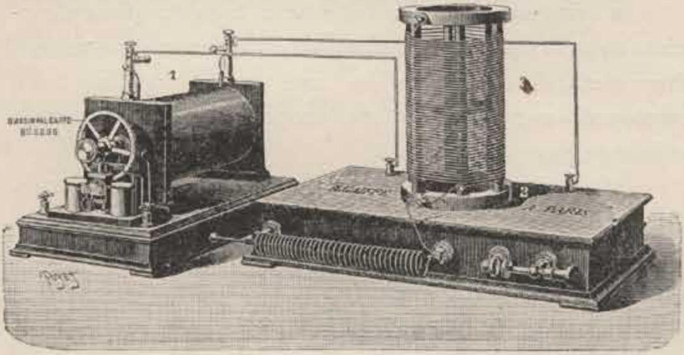

Fig. 45.

In fact, feeble as may be the capacity, the charge and discharge, repeated hundreds of thousands of times per second at a high potential, represent a notable mean current.

It is this that explains the uni-polar currents, and the sparks that occur when any point on the solenoid is touched. In this case the body, constitutes an insulated surface which, at each oscillation, is charged with a very nearly constant quantity when it is at a certain distance from the solenoid.

The corresponding charge of contrary sign should be found on the parts of the solenoid which are at that moment at a different potential. This explains why the sparks which are drawn from the solenoid are greatest at the extremities and least midway.

3d. The resonant effects, which have been so beautifully shown by the experiments of Hertz, and which are extremely interesting to the physicist, but which have not, so far, been found to have any relationship to therapeutics.

METHODS OF APPLICATION.

In bringing the action of these high frequency currents to bear upon the human and other animal organisms three methods of application have up to this time been employed—suggested by the properties of the current which we have enumerated.

1st. Auto-conduction. In this mode of application the capacity of the current to induce currents in objects brought within their range, is utilized. In place of the small solenoid above described a much larger one is employed, composed of well insulated cable wire, and wound about a frame work capable of admitting into its interior the man or animals to be treated. Although the person enclosed in the solenoid is not in contact with it at any point, nevertheless, while it is in action, induced currents of extreme energy and frequency of oscillations are induced in his body. These induced currets have their seat in the organism itself and act upon the central nervous system and deep seated organs and tissues as is shown by the effects produced and recorded in the following article on the physiological action of these currents.

2nd. The direct application. This is made by conducting the currents generated in the small solenoid, or the currents of second order, to any part of the body by means of conducting wires and metallic electrodes and thus making the body as a whole, or any part of it, as the case may be, a part of the circuit.

3rd. Insulation. In this method the patient, person or animal, to be subjected to it is placed upon an insulated platform and connected by a wire to one extremity of the solenoid while a point, metallic point or plate, at some little distance from the insulated platform is connected with the other extremity of the solenoid. The person acted upon is thus, as it were, made to take the place of one of the armatures of a condenser and is subjected to a charge which is slowly discharged by connection across the interval between the body and the conductor leading to the other extremity of the solenoid.

PHYSIOLOGICAL ACTION OF HIGH TENSION, HIGH FREQUENCY CURRENTS.

This form of electric modality, except as it is furnished by static or influence machines has not so far been studied in its relation to physiological action by many persons. Several notable electricians as Nikola Tesla, Elihu Thomson and Hertz have done much to acquaint us with the apparent harmlessness of this form of electricity when the living animal body, or some part of it, is made the path of its transit. But to d'Arsonval and his assistants the credit is mainly due for having determined with scientific exactness and demonstrated by unquestionable proofs that this electric modality does in many ways modify physiological processes most profoundly. While we have for a number of months been using this form of electricity in this laboratory, as generated by both the Tesla and the Thomson forms of apparatus, we have, so far, done little with it other than to confirm many of the results that d'Arsonval has reached and which he has published from time to time in the transactions of the Société de Biologie and of the Société Internationale de Physique.

What is set forth here, therefore, as the result of investigation as to the relation of this form of electricity to physiological action in the animal body, and which may be regarded as fully established by abundant experiment, is given mainly on the authority of d'Arsonval, and to the detailed reports of his researches we would refer any who may wish to examine into the data upon which the following conclusions are based:

1st. The most singular and striking effect of high-tension, high-frequency currents is their entire absence of action on sensation. This is daily demonstrated in this laboratory. When the Tesla apparatus is excited by an alternating dynamo current and is pouring forth a torrent of sparks between the terminals, across an air gap of eight or ten inches, one can grasp these terminals, one in each hand, and take the entire current through the body without experiencing the slightest sensation except, perhaps, one of gentle warmth at the wrists when the current reaches, or exceeds three amperes. To demonstrate the actual energy that is being expended during this procedure it needs only to have two persons grasp these terminals each with one hand and then complete the circuit by taking several incandescent lamps in series between them, when the lamps, requiring each an ampere of current and 100 or more volts to light them, will glow brilliantly while the current is passing.

When the current is caused to impinge upon a limited surface of the skin or mucous membrane in the manner which in treatments by the static machine is termed "the breeze" the part is soon benumbed and for a few moments experiences the loss of sensibility which may go on to complete anaesthesia. This insensibility does not penetrate deeply and lasts only a few moments, but that it may be made to serve important therapeutic needs is at once evident to a physician.

2d. These currents do not excite muscular contractions. Just as the passage of these currents through the organism fails to arouse sensation so likewise motor nerve and muscle are irresponsive to them. While the same quantity of electric energy transmitted under the form of alternating currents of long periods (100—10,000) and much less voltage, would have caused violent muscular contractions, which of themselves would suffice to kill the recipient, here no contraction whatever occurs.

But just as a sensory nerve when subjected to the direct action of these vibrations for a time is rendered anaesthetic, so a motor nerve may be influenced in such manner by these currents as to be for a brief period (10 to 15 minutes) incapable of responding to any form of excitement.

3d. The high-tension, high-frequency currents impart an extraordinary activity to nutritive changes and to cellular life.

This has been demonstrated.

(a) By examining and estimating in man and animals the products of respiratory combustion before and after the action of the current. The oxygen absorbed is seen to be increased considerably and carbon dioxide is eliminated in greater quantity.

(b) By the amount of urea being greatly increased in quantity, as has been determined by hundreds of urinary analyses.

(c) By an increased heat production, which has been carefully determined by an ingenious anemo-calorimeter devised by d'Arsonval. By this instrument it has been established that by comparing the heat put forth by the human body before and after this method of electrization, it is found to raise it from 79.6 cal. to 127.4 cal. per hour at an average temperature of 17° C.

(d) By a loss of weight in the men and animals experimented on during the period of application. This would of necessity be the primary result of the increased combustion. But it was found that in the intervals between the applications of the current there was a rapid gain in weight.

4th. While there is no perceptible action of these currents on the nerves of general sensibility and of voluntary muscle, the vaso-motor nervous system which controls the vascular system is influenced by these currents to a marked degree. The blood vessels in the ear of the rabbit are seen to dilate rapidly under its action and this is followed a little later by energetic contraction. The same results take place in man as determined by the sphygmograph and sphygmomanometer. The blood pressure is at first lowered and after a little time rises and remains elevated.

5th. Action on unicellular organisms. In order to determine the direct action of these high-frequency, high-tension currents on cellular physiology many forms of bacilli were subjected to their influence. The cultures of the pyocyanic bacillus were very much attenuated at the end of some minutes. The chromogenous function is first suppressed and if the experiment is continued for half an hour the baccilli are killed.

The action of these currents is found to modify also the products of the secretion of bacteria. The microbic toxines are found to readily lose their virulence when subjected to this electric modality for a short time.

D'Arsonval and Charrin have carried on a series of experiments for some months to determine the modifying action of various forms of electricity on the growth and behavior of bacteria the results of which were reported to the French Academy of Sciences, February 10th, 1896. Their experiments have shown that cultures of bacteria are affected more or less by the action of the constant or galvanic current, the interrupted induced current of low tension and frequency, and also by the high tension, high frequency currents. The action of the latter seems to be most effective both in retarding the growth of pathogenic bacteria and in weakening the virulence of their toxine products. As has been elsewhere noted, the action of the constant current upon culture media is attended by electrolysis and is a difficult matter to determine, when this current is used, just how much of the result is to be attributed to the electric action directly and how much to the action of the liberated ions. It is fair to presume that the changes wrought by the high tension, high frequency currents are the result of the electric action solely since being alternating currents but little electrolytic decomposition attends them.

The experiments upon bacterial toxines by means of high frequency, high tension currents and the subsequent tests made with the solutions containing the toxines thus acted upon, not only seem to show that the toxic power is reduced, but also that the animal receiving such injections is rendered immune, or its resisting power to such toxines is greatly increased. From this the hope is entertained that by means of the application of such currents it may, eventually, be possible to so attenuate bacterial products in the organism of a patient as to render him immune to the disease.

6th. The clinical results are also in evidence to prove the modifying influence which electricity in this form exerts upon physiological action, and while these are not as yet very abundant they are already sufficient in amount and importance to establish the value of this unique manner of treatment, and are deserving of separate consideration in the following article.

THERAPEUTICS OF HIGH POTENTIAL, HIGH FREQUENCY CURRENTS.

Those who have been long familiar with the results obtained from treatments by means of the static machine cannot but be struck with the similarity of these with what has recently been set forth by D'Arsonval, Apostoli and a few others as the results of their experience in the therapeutic use of high frequency currents obtained through the variously devised forms of apparatus that they have employed. Especially do the results on general nutrition obtained by the spark and insulation methods of treatment by the static machine closely correspond with those reported as resulting from the inductive action of the large solenoid. The assertion which is often made that "suggestion" is accountable for much that is reported as resulting from this as from other forms of electric treatment falls to the ground in the face of the exact methods of analysis that have been adopted in determining the effects of these currents on patients in the public clinic and upon the growth of infants in the Maternity hospital. But the field is open and those who doubt may readily put all assertions to the proof.

We perhaps cannot do better in our attempt to set forth the present state of opinion as to the therapeutic range and value of this peculiar electric modality than to give as succinctly as possible the conclusions of Apostoli, whose clinical experience in this field has been up to the present time far more extensive than that of any other practitioner.

They are as follows:—

1st. The alternating currents of high tension exercise a powerful action on every living organized body which is submitted to their influence.

2nd. The best method of treatment by means of these currents is to enclose the patient, without any contact whatever, in a large solenoid traversed by the current. The patient is thus completely insulated from the electric source and the currents which circulate by "auto-conduction" in his organism have their origin, by induction, in the tissues themselves. The body here plays the part of a closed circuit.

3rd. The powerful influence on the vaso-motor system claimed for these currents by d'Arsonval has been verified, although the sensation immediately produced by their passage is nil, and there is no impression made by them on motor nerves or muscles. But an energetic action on all nutritive exchanges may be noticed. This action shows itself by an over-activity of organic combustions and of nutrition, as has been shown by the analysis of the respiratory and urinary excretions made by d'Arsonval, Berlioz and others.

4th. The general therapeutic applications which follow from this physiological action are confirmed in the clinic.

At the time of this report (made at the London congress in '95) Apostoli had in this manner treated more than one hundred patients, covering a period of a year and a half, some in his office and some in his public clinic. The greater number of them were much benefitted by this method, which was used to the exclusion of all other treatment or medication.

5th. These currents exercise, in the majority of cases, a powerful and generally reparative action on diseases caused by or attended with feeble nutrition, by accelerating the organic changes and by increasing the activity of enfeebled or perverted combustion and elimination. Diuresis becomes generally more satisfactory and excretion is hastened.

6th. Generally in patients submitted to this influence daily for about 12 minutes the following effects are noticed about in the order named:—

Return of sleep.

Increase in force and vital energy.

Return of good feeling, capacity to work, ease in walking, increase of appetite.

Progressive and complete restoration of the general health.

Often from the first sittings and even before the special and local effects noticed as changes in the excretions, etc., an amelioration of the general ill-state can be plainly noted.

7th. The local troubles, pains or trophic disturbances, subside generally much more slowly under the modifying influence of these currents than general nutritive disorders. In many cases such local disorders require the addition of local treatment.

8th. Of all the diseases, which up to the present seem to yield to this treatment, rheumatism is most energetically and effectively influenced.

9th. In some cases of diabetes the sugar has rapidly disappeared from the urine, while in others it has not been perceptibly diminished in spite of the manifest improvement in the general state. This difference in result may be due to a lack of uniformity in technique or to different pathological conditions.

To sum up in the words of d'Arsonval, electricity in the form of high tension, high frequency currents is the most powerful modifier of the intimate nutrition of the tissues that we know.

It is a modifier which attacks life in its most intimate manifestations and which touches the working of the living cell itself. Its action extends even to the products of the cell. As these currents can with impunity traverse the organism of living man there is no temerity in saying that by means of them an entirely new road for therapeutics is opened up.